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CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

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COUNTRY USSR

SUBJECT Comments and Review of USSR Books on Deformation of Steel/Ternary and Quaternary Phase Diagrams

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THIS IS UNEVALUATED INFORMATION

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1. S. F. Yur'yev: Deformation of Steel During Chemico-Thermal Treatment - Carburizing and Nitriding. Moscow (1950). 311 pp.

a. A thought-provoking and fascinating, although rather frustrating, book.

(1) First consideration is given to the "laws" governing the diffusion of carbon or nitrogen into steel. Neither the carburized nor the nitrided case, however, exists alone as a homogeneous unit. Each has a gradient of carbon or nitrogen and each is in intimate contact with a core having a different composition. Case and core, consequently, mutually affect each other's behavior and properties. One result of this interaction is the formation of certain residual stresses, which place the case in compression and the core in tension in the finished part. (These surface compressive stresses are believed the cause of the improvement in properties such as fatigue strength and notch sensitivity brought about by carburizing or nitriding.) Yur'Yev then turns to a detailed analysis of the effect of many factors on size changes and residual stresses during carburizing and nitriding. Nitriding represents the simpler case, since the stresses are set up during the nitriding operation itself and no further treatment is needed. The picture is far more complex and less easily resolved with carburized parts, as they require hardening subsequent to the carburizing operation to develop the required properties; the surface compressive stresses arise only during the final hardening at temperatures below about 930/1020 F.

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(2) Most of the data appear original despite the 193 references. (Only some 15% are non-Russian; about half of these are pre-1940.) The experimental work was done predominantly with a differential dilatometer. Yur'yev has, however, made ingenious use of some other techniques, such as miniature tensile specimens to determine the mechanical properties at various tempera- 25X1 tures of case and core during cooling from the austenitizing temperature.

b. This book seems [redacted] to have certain basic weaknesses.

(1) The title is somewhat misleading.

(2) The book hardly seems suitable for "engineering and technical workers in the field of metallurgy and heat treatment of steel". It would have been more easily understandable to a wider audience if much of the detailed experimental data and mathematical derivations had been placed in appendices.

(3) It is not clear how Yur'Yev's data could be applied to irregular parts, such as gears, which make up a sizeable proportion of the tonnage of carburized and nitrided parts.

(4) The value of the book would have been greater if more attention had been paid to actual mechanical and metallurgical properties - and perhaps even service performance - of carburized and nitrided parts.

(5) Excessive reliance appears to be placed on dilatometric data. There is some doubt as to the accuracy of the derived residual stresses, as compared to determinations by more conventional but likewise more complicated test methods.

<u>Surface Stressing of Metals</u>. ASM (1947). 197 pp.

<u>Symposium on Internal Stresses in Metals and Alloys. The Institute of Metals (1948). 486 pp.</u>

<u>Residual Stress Measurements</u>. ASM (1952). 210 pp.

A. L. Christenson and E. S. Rowland: <u>X-ray Measurement of Residual Stress in Hardened High Carbon Steel.</u> TASM 45 (1952) pp. 638/666; disc. 666/676.

(6) The basic problem of heat-to-heat variation is not given full cognizance. The test material was one heat of aluminum-chromium-molybdenum steel, and two heats each of carbon, chromium-nickel and chromium-molybdenum-nickel steel. Where two heats of the same grade were used, different final sections were involved. Therefore, there is no indication of the variation that might be found if a number of heats of the same grade were tested.

(7) Yur'yev's metallurgy seems rather shaky in places, as in the discussion of direct quenching after carburizing, low-alloy carburizing steels, harden-ability and the effect of alloying elements.

c. Increasing attention is being given to size change during heat treatment by mass-production industries in the US since there is a growing tendency to heat treat after finish machining, or to leave only a small allowance for final finishing.

(1) Yur'yev does not distinguish adequately between distortion and (allotropic) volume changes, which arise from different causes.

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(2) Yur'yev does not take into consideration other factors, such as hardenability and modified quenching practices, that are of vital importance. The foreword by N. T. Gudtsov also hints that Yur'yev does not cover the practical methods used to control size change.

(3) Some of the factors not considered by Yur'yev are discussed by Hense, Miller and Schenck of Buick Motor Division of General Motors Corp:

> "In the hardening of automotive gears it is desirable to produce the required physical properties with the least dimensional disturbance. Distortion can be caused by stresses from machining, non-uniform heating and carburizing, and variation in the hardenability of the steel.
>
> "The maintenance of uniform distortion during the heat treating operation is, without a doubt, the most important factor in the production of high quality gears. The tooth cutting is changed on the drive pinion, as necessary, to allow for distortion during heat treatment...In order to control the quality of the gears coming from the heat treating operations, it is necessary to run pilot lots of each new heat to determine the distortion characteristics. At the same time it is necessary to run daily checks on production to control the quality of parts coming from the heat treat...The variation in hardenability from one heat of steel to another makes control a necessity, and the narrower the hardenability spread of the steel, the better chance the metallurgist has to produce uniform gears...
>
> "Experience has shown that a factor influencing distortion to a very marked degree is the carbon content of the carburized case. The maximum carbon content of the case has an effect upon the hardenability which, in turn, influences dimensional changes during heat treatment."

V. E. Hense, H. H. Miller and R. B. Schenck: Economics of Automotive Gear Steels and Their Heat Treatment. SAE preprint 481 (1950). Excerpts in SAE J 58 (1950) no. 10, pp. 25/29.

(4) In the case of nitrided parts, Yur'yev does not consider adequately the effect of microstructure nor the fact that size change may be greatly affected if the "white layer" is ground off after nitriding.

d. Although the general distribution of residual stresses in carburized and nitrided parts has been surmised, very little comprehensive information has been published in this field. (A large part of the previous work is covered by the following references.) Moreover, as pointed out by Horger, the subject of residual stresses due to carburizing has generally been oversimplified. Yur'yev's book is a distinct contribution

J. O. Almen: Fatigue of Metals as Influenced by Design and Internal Stresses. Surface Stressing of Metals. ASM (1947) pp. 33/84

J. O. Almen: Fatigue Weakness of Surfaces. Product Engineering 21 (1950) no. 11, pp. 117/140.

O. J. Horger: Residual Stresses. Handbook of Experimental Stress Analysis. New York (1950) pp. 459/578.

D. G. Richards: Relief and Redistribution of Residual Stresses in Metals. Residual Stress Measurements. ASM (1952) pp. 129/195.

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(1) Again, however, Yur'yev has passed over some factors of vital practical importance, such as hardenability, as discussed by Boegehold:

> "Success of carburized rear axle gears depends also upon a highly uniform shape of teeth to insure uniform load distribution, along with high residual compressive stresses in the case to oppose the stresses from externally applied loads...to obtain favorable stresses...it is necessary to control hardenability within narrow limits...This same control of hardenability will also assist in uniformity of size change (distortion from hardening) which can be compensated for when cutting the gear teeth in the green. The volume changes associated with transformation in the case and core, therefore, must be held as uniform as possible, both as to magnitude and sequence.
>
> "Rear axle ring gears, drive pinions, transmission gears, bearing races and all such highly stressed, high-hardness parts can be greatly benefited by close control of hardenability. The prime reason for this, again, is to prevent unfavorable trapped stresses, rather than to insure certain microstructures and hardness."

A. L. Boegehold: Hardenability Control for Alloy Steel Parts. Metal Progress 53 (1948) pp. 697/709.

(2) Yur'yev stresses the effect of compressive stress (imposed by prior transformation of the core) on the temperature and rate of transformation of the carburized case. Although there has been some work on the effect of stresses on the transformation of austenite, the significance of this factor in the case of carburized steel has not been previously emphasized.

V. I. Prosvirin: Effect of Pressure on the Transformation of High Speed Steel. Vestnik Metallopromishlennosti 20 (1940) no. 7. pp. 55/61.

G. K. Manning: End-Quench Hardenability Versus Hardness of Quenched Rounds. Metal Progress 50 (1946) pp. 647/652.

G. J. Guarnieri and J. J. Kanter: Some Characteristics of the Metastable Austenite of 4 to 6% Chromium + 1/2% Molybdenum Cast Steel. TASM 40 (1948) pp. 1147/1164.

M. D. Jepson and F. C. Thompson: The Acceleration of the Rate of Isothermal Transformation of Austenite. JISI 162 (1949) pp. 49/56.

H. Neerfeld and K. Mathieu: Zum Machanismus der Umwandlung des Eisens. Archiv fur das Eisenhuttenwesen 20 (1949) pp. 69/73.

M. Cohen: Retained Austenite. TASM 41 (1949) pp. 35/94.

M. Cohen, E. S. Machlin and V. G. Paranjpe: Thermodynamics of the Martensite Transformation. Thermodynamics in Physical Metallurgy. ASM (1950) pp. 242/270.

B. L. Averbach, S. G. Lorris and M. Cohen: Stress-Induced Transformation of Retained Austenite in Hardened Steel. TASM 44 (1952) pp. 746/756; disc. 756/757.

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e. Both of the main factors considered by Yur'yev - size change and residual stresses - are of increasing importance today. There is, as far as is known, no book in English dealing exclusively with these subjects. If Yur'yev's book is accepted as an interim report on the development of the theoretical aspects of carburizing and nitriding, some of its inadequacies can be overlooked and its true value properly evaluated.

2. B. E. Volovik and M. V. Zakharov: Ternary and Quaternary Systems. Moscow 1948. 227 pages.

a. An excellent manual, dealing exclusively with the theory and mechanism of constructing ternary and quaternary phase diagrams. Obviously it would be suitable only for graduate students or others already thoroughly acquainted with binary phase diagrams. Both parts of this book are written sufficiently simply and explicitly, however, that metallurgists so qualified would be able to construct ternary and quaternary diagrams without additional guidance.

b. As far as is known, there is no book in English devoted solely to this subject. It could be considered, however, more or less as a supplement to J. S. Marsh's Principles of Phase Diagrams (McGraw-Hill Book Company, Inc.). Since Marsh's book was published before World War II, and therefore before ternary and quaternary diagrams became as much used as they are today, a better comparison can be made with the combined seventh-eighth edition of the classic Einfuhrung in die Metallographie, by P. Goerens, as revised by P. Schafmeister and H. J. Wiester. Moreover, this German textbook was published by Wilhelm Knapp in 1948, the same year as the Volovik-Zakharov book appeared. The German book devotes 40 pages to principles and construction of ternary diagrams, but none to quaternary diagrams. Of the Volovik-Zakharov book, 110 pages are devoted to ternary diagrams, and 111 to quaternary. This comparison is quite a tribute to the state of metallurgy and metallurgical education in the USSR in view of the value placed on phase diagrams and theoretical metallurgy of this type in Germany.

c. The high quality of the Soviet work in this field is seen by other publications using ternary and quaternary diagrams, such as the work of E. E. Kornilov, to whom acknowledgement is made in the introduction.

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